

NAVAL WAR COLLEGE
Newport, RI

**21st Century Technology in Air power:
A Double-Edged Sword**

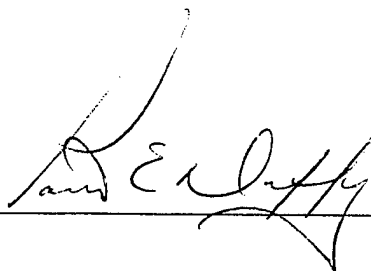
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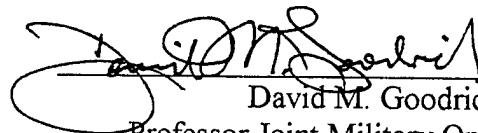
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The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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CONTENTS

ABSTRACT	iii
INTRODUCTION	1
PRECISION GUIDED MUNITIONS	3
CAPABILITIES	5
LIMITATIONS AND UNINTENDED CONSEQUENCES	6
Political and Public Expectations	6
Self Imposed Employment Limitations	8
Limitations in Targeting Information	10
Cost Imposed Limitations	13
JUST BECAUSE WE CAN, SHOULD WE?	14
CONCLUSION	17
ENDNOTES	20
BIBLIOGRAPHY	23
APPENDIX	
A A BRIEF SUMMARY OF NEW TECHNOLOGIES IN AIRPOWER	A1
B JDAM	B1
C SUMMARY OF GULF WAR TARGET-TO- SHOOTER COMPARISONS	C1
D CONSTANTLY COMPUTED IMPACT POINT FOR UNGUIDED BOMBS	D1
E AIR TARGETING DOCTRINE	E1

ABSTACT

21st century air power brings new capabilities to a Commander in Chief (CINC) and Joint Task Force (JTF) Commander, but it also brings significant limitations, and occasionally unintended consequences, particularly in a politically constrained war.

New technologies have resulted in air power enhanced capabilities that include increased accuracy and survivability leading to an increase in vulnerable targets and overall air power effectiveness. Other positive results include increases in surprise, maneuver, and offense as well as reduced requirements in logistics support, force protection and security.

At least as important as the capabilities provided by new technology, are a variety of significant limitations and potential unintended consequences. These include recently increased public and political expectations, which can unexpectedly lead to an ill-timed war termination and prolonged military presence, or an overall less effective operation. Next, heavy intelligence demands to accommodate precise targeting and damage assessment, particularly against mobile targets, can result in outdated or incomplete information leading to adverse strategic effects. Finally, airmen are approaching (and may even have achieved) the survivability and precision always stipulated by current doctrine as a requirement to the effective use of air power. But historic evidence suggests a need to question existing doctrine in light of its lack of success in causing an enemy leader to concede as a result of the destruction of civil infrastructure or an induced popular uprising.

Failure to consider these limitations in the use of new technologies may result in at least a less effective operation but could also include unachieved operational or strategic objectives and possibly even loss of national prestige or embarrassment.

INTRODUCTION

21st century air power brings new capabilities to a Commander in Chief (CINC) and Joint Task Force (JTF) Commander, but it also brings significant limitations, and occasionally unintended consequences, particularly in a politically constrained war. Advances in aerospace technology have been both continuous and dramatic since man's first flight, and continue today at an impressive rate. Recent evidence of these advances are apparent in the continued development of a variety of capabilities including precision guided munitions (PGMs), radar-evading "stealth" technology, integrated avionics systems, and advanced engine design to name only a few. Woven together, these capabilities can provide results typified in the now almost trite video footage of 'smart' bombs flying into the windows or cooling shafts of targeted buildings.

These remarkable advances in a variety of technologies were designed to significantly enhance the combat capability of the CINC and JTF Commander in the theater, and this trend toward increasing technological capability in air power is unlikely to abate. The Honorable Dr. Jacques Gansler, Under Secretary of Defense for Acquisition, Technology and Logistics, testified to the Senate Armed Service Committee that the FY2001 budget request included (after inflation) an 8% increase in research and development, and a 12% increase in procurement over the FY2000 budget.¹ Increased funding in today's fiscally constrained defense budget environment dramatically underscores this country's demand for continued increases in aerospace technology.

However, these new capabilities can also become a two-edged sword for a CINC. In the aftermath of the Gulf War, Desert Storm, and Kosovo, Operation Allied Force, the American public and politicians have come to expect that in many cases high-tech air power

solutions are the “one size fits all” panacea for our country’s military problems. The new and evolving capabilities in air power have certainly provided the CINC and JTF Commander many outstanding tools and options, but they also involve very real limitations and potential unintended consequences, which must be understood in the context of existing political and environmental conditions. What appeared easy in the open-desert environment of Iraq, in conjunction with the relatively “hands-off” approach of the Bush administration, belied our ineffectiveness in destroying high-priority targets such as mobile Scud launchers and Weapons of Mass Destruction (WMD) research facilities. In the case of the Iraqi nuclear weapons program, for example, despite the initial belief at the end of Desert Storm that most of these facilities were destroyed, the subsequent UN Security Council inspection teams identified and destroyed more of Iraq’s nuclear missile programs than had the air campaign.² More recently, the more difficult, hilly, urban environment of Kosovo and the consensus-oriented NATO alliance force made effective employment of air power difficult despite the enormous technical edge enjoyed. While the air operation (along with other diplomatic, economic and military influences) brought Milosevic to the bargaining table, it was clearly ineffective in significantly damaging his disbursed army or stopping the ethnic cleansing he pursued in the meanwhile.

This paper examines the implications of technology advances in air power from the operational perspective of a CINC or JTF Commander. In order to allow a more complete analysis, the focus has been narrowed to primarily the capabilities, limitations and unintended consequences of PGMs. It is important to appreciate, however, that the technology advances in air power are actually synergistic in achieving battlespace success. Advances in one technology build upon advances in other technologies to achieve a result greater than either one alone could provide. For example, integrated avionics combines data from a variety of sensors,

both internal and external to the aircraft, to provide a single “fused” picture of information. But when it is coupled with PGM capability, it results in the what is termed precision engagement, or “...the ability to find, fix, track and precisely target any military target”³ (Appendix A provides additional detail in describing these technologies). Because of this synergy, many of the issues raised in this paper may apply equally to other technologies. Awareness of these capabilities and limitations will help the CINC shape the best force for a contingency. Perhaps more importantly, it will also help the CINC avoid the increasingly significant risk of either accepting or providing unrealistic timelines and endstates to the American public, National Command Authorities, or our global allies/coalition members when relying heavily or solely on air power in future conflicts.

PRECISION GUIDED MUNITIONS ⁱ

Recent advances in technology have made PGMs much more affordable and increasingly available, but they are not new. In fact, laser- and TV-guided bombs were first introduced during the Vietnam War after many costly missions were repeatedly flown against the same small targets. For example, over 350 sorties using unguided bombs were flown against the heavily defended Thanh Hoa Bridge before it was finally destroyed after only 2 LGB missions⁴. Laser-Guided Bomb (LGB) introduction during Linebacker I, the April-October 1972 Vietnam air campaign, allowed several important railroad bridges and tunnels near the politically sensitive Chinese border to be targeted without fear of political complications.⁵ Ultimately, over 4,000 LGBs were dropped on North Vietnam between April

ⁱ Precision guided munitions include air-to-air missiles, air-to-ground rockets and missiles, and guided bombs. This paper will only consider the latter two categories. Examples include laser- and TV-guided bombs (GBU-24, GBU-27 and AGM-130), IR-guided rockets (Maverick, AGM-65), High Speed Anti-Radiation Missiles (HARM, AGM-88) and GPS-guided bombs (Joint Direct Attack Munition, JDAM). Although the 13m contractually specified accuracy of the JDAM slightly exceeds the commonly accepted accuracy associated with “precise” weapons, it will be considered a PGM for the purposes of this paper since JDAMs were often used to attack targets normally requiring a “precise” munition in Kosovo.

1972 and January 1973.⁶ Since that time, PGMs have become more capable and cheaper because of advances in technology. The current cost of a strap-on “tail kit” which transforms a “dumb” Mk-82 to a “smart”, GPS-guided PGM is roughly \$14-18,000 each, which makes the remarkable improvement in accuracy achieved relatively affordable.⁷ Appendix B contains additional information about the JDAM.

Likewise, the idea of “precision” bombing is also not new, but its empirically based definition has evolved dramatically since WWII. Before WWII, U.S. Army Air Forces had advanced bombing techniques (in part due to the new Norden bombsight) to the point of coining the phrases “pin point” and “pickle barrel” bombing. Unfortunately, these phrases were based on benign target range conditions and a relative perspective of what was considered “precise”. Later, significantly less impressive results were achieved in combat. During the bombing of Europe in WWII, many limiting factors intervened: target obscuration by cloud, fog, and smoke screens; enemy fighter opposition, which led to formation bombing; antiaircraft artillery defenses; and limited training opportunities. The result was that, during less benign (combat) conditions, only about 20% of the bombs aimed at precision targets fell within a 1,000-foot circle around the aiming point.⁸ Since that time accuracy has improved dramatically so that the use of the term “precision” may be considered more appropriate. The typical Circular Error Probableⁱⁱ (CEP) associated with “precise” bombs of today are less than 10m. A single aircraft dropping a single PGM can now have the “massing effect”ⁱⁱⁱ of many sorties and bombs. In 1944, roughly 1,000 aircraft sorties dropping over 9,000 bombs were required to

ⁱⁱ CEP is the radius of a circle within which 50% of the bombs dropped will fall.

ⁱⁱⁱ In defining the principle of war “mass”, Joint Pub 3.0 indicates that “Massing effects, rather than concentrating forces, can enable even numerically inferior forces to achieve decisive results and minimize human losses and waste of resources.”⁷

successfully hit one target.¹⁰ In contrast a single laser-guided bomb accomplished the same effect during Desert Storm.

CAPABILITIES

The implications of this much-improved accuracy on the principles of mass and economy of force are striking. In comparing 12 representative Desert Storm sorties comprised of F-117s and F-111Fs carrying laser-guided bombs to 12 sorties flown in Operation Proven Force^{iv} in which F-111Es carried unguided bombs, several points emerge. First, the 12 Operation Proven Force sorties covered 2 distinct targets, while the 12 Desert Storm sorties covered 26 targets with 28 bombs. The target/sortie ratio for the “dumb-bomb” sorties was 1:6, but the laser-guided bomb carrying sorties had a 2:1 ratio. The precision to non-precision ratio of targets-to-sorties is thus 26:2, or 13:1--an order of magnitude difference.¹¹ In addition, the precision guided munitions had substantially higher probabilities of hitting the individual Designated Mean Points of Impact^v (DMPIs) than the unguided bombs. The distinctions that are manifest by this technology are significant in a variety of ways. Because of a higher target to sortie ratio, aircraft carrying PGMs may be fewer in number and also require fewer bombs to destroy the same number of targets (Appendix C contains a brief summary of related Desert Storm information). This could lead to a smaller logistics “footprint”, or support requirement, for PGM equipped aircraft than for aircraft without PGMs. A smaller aircraft footprint means more sea- and airlift could be dedicated to transporting other resources. In addition, since fewer aircraft would be exposed to the threat, surprise could be more likely, and the burden of security for the reduced force may be decreased. These impressive characteristics have not

^{iv} Proven Force sorties were flown from Turkey against northern Iraqi targets.

^v A DMPi is the specific aimpoint on the target. Greater precision has made it possible to select, for example, a cooling duct rather than an entire building. This allows decreased collateral damage and a better-defined effect.

escaped the notice of politicians and the NCA, who have placed an increasingly heavy reliance upon them.

As a result of technology, PGM effectiveness has steadily increased since the Vietnam War. One measure of that effectiveness, particularly important in a politically constrained war, is in limiting collateral or unintended damage. Only 20 of the roughly 23,000 munitions expended by NATO in Operation Allied Force caused collateral damage.¹² In light of this and the overall effectiveness of guided weapons, the Kosovo After-Action Report to Congress called Operation Allied Force "the most precise military operation ever conducted."¹³ In order to take advantage of this effectiveness, the number of U.S. strike aircraft capable of carrying PGMs has increased from only 10% in the Gulf War to over 90% in Operation Allied Force.¹⁴ Clearly, the continued evolution of PGMs has brought, and will continue to bring, impressive combat capability in providing high Probability of Kill (P_k) precision targeting.

LIMITATIONS AND UNINTENDED CONSEQUENCES

At least as important as the capabilities provided by new technology, are a variety of significant limitations and potential unintended consequences. A CINC must consider this less obvious information in order to make an informed assessment of the relative risk he may accept in using this technology. Failure to consider this aspect of the use of new technologies may result in at least a less effective operation but could also include unachieved operational or strategic objectives and possibly even loss of national prestige or embarrassment.

Political and Public Expectations

First among these limitations is that the widely proclaimed successes of advanced technology air power have set the public and political expectations "bar" very high. Desert Storm concluded with the loss of only 13 fixed-wing aircraft, and in Allied Force, only 2 U.S.

fixed-wing aircraft were downed and no airmen were killed.¹⁵ On the other side of this coin, as already noted, there were very few cases of collateral damage during Allied Force, largely because of the extensive use of PGMs and significant political constraints on targeting. Similarly, during Desert Storm it became clear to the Iraqis that the U.S. was typically targeting equipment rather than the men operating it. There were many stories of Iraqis taking shelter by moving away from their equipment because of this awareness.¹⁶ The consequences of relatively few or no losses of U.S. lives, coupled with the impression of highly effective equipment (rather than human) targeting, has led the American public and politicians to perceive an emergence of virtually bloodless warfare. Unfortunately, war is not bloodless. During Desert Storm, this fantasy was challenged at Mutla Ridge, better known as “The Highway of Death”, with enormous strategic implications. Air power was used to destroy the leading vehicles and then the trailing vehicles escaping from Kuwait City along the highway. This set the scene for pilot commentary quoted in the *Washington Post* as, “shooting fish in a barrel”, and “a turkey shoot”.¹⁷ The accompanying photographs portrayed the deadliness of the war, which was not considered noble or bloodless. Despite President Bush’s assertion that the exodus was not a withdrawal as Saddam Hussein initially indicated, but an armed retreat being pursued, public and political opinion swayed toward disapproval.¹⁸ Within days, a cease-fire was hurriedly arranged to avoid the perception of butchering the Iraqis.¹⁹ Unfortunately, the effectiveness of the precision weapons resulted in an incomplete or early end to the Gulf War. The end was early in the sense that the major objective of destruction of the Iraqi Republican Guard had not yet been accomplished. In fact, General Schwarzkopf’s initial goal was not to defeat the Republican Guard, nor to make it combat ineffective, or chase it out of southern Iraq, but to utterly destroy it.²⁰ The rapidly arranged cease-fire declared in the absence of achieving

this objective to avoid the sense of “piling on” suggests an unintended political consequence of vastly superior combat effectiveness. The end was also early in the sense that the assigned mission was incomplete. Without ensuring that the adversary’s surviving force was considerably less capable, or that the Iraqi national will was adversely affected, the U.S. finds itself still flying missions in support of the continued “No-Fly” Operations Southern and Northern Watch almost 10 years after the “end” of the war.

The point of this example is that recent U.S. experience with PGMs has resulted in a very effective combat force, but also some unanticipated political ramifications. The ability to strike very precise DMPs on structures and equipment has resulted in a greater demand for decreased collateral damage, and less bloodshed (because we can, we must), sometimes even at the expense of *overall* effectiveness. Further evidence for this conclusion is supported by the politically expedient, but militarily questionable decision to announce to the world *a priori* the plan not to introduce NATO ground forces into Kosovo. While this decision may have addressed a NATO or U.S. desire for a more bloodless war, it did little to improve the effectiveness of the overall operation or the ability to decrease the ethnic cleansing.

Self Imposed Employment Limitations

A second limitation or unintended consequence that must be considered in using PGMs is associated with an evolution in supplemental Rules of Engagement (ROE), which were initiated as a prudent self-protection measure. Unfortunately, this limitation has evolved into a “one size fits all” altitude restriction to accommodate the desire for a bloodless war. Three days after the start of the air war in Desert Storm, the Joint Forces Air Component Commander (JFACC) announced his decision to change the ROE by requiring airmen to operate above 10-15,000 feet in order to avoid enemy air defenses.²¹ This change was imposed because of the

unacceptable initial losses sustained during low altitude operations (relative to the military value of the targets prior to the land war) *and* because of the belief that long-range (standoff), precision bombing was possible. While this restriction was certainly defensible for aircraft carrying PGMs in clear weather prior to the ground war, it may not be a good “one size fits all” solution to the balance between force protection and overall effectiveness. Specifically, although over 90% of U.S. aircraft are now PGM capable, only 35%^{vi} of the munitions expended in Kosovo were PGMs.²² The accuracy and effectiveness of the remaining unguided bombs dropped using the higher altitude release restriction suffered as a result of the limited visual acuity of a pilot at these greater distances (a pipper, or aiming “dot”, may obscure an entire building at longer ranges, making it difficult to select a specific DMPI) and ballistics algorithms.^{vii} Ultimately, because of the resulting ineffectiveness, this restriction was changed to allow A-10s and some F-16s to release as low as 4,000 feet.²³ The remainder of the aircraft, however, continued to suffer in effectiveness as a result of the altitude restriction.²⁴ In addition, during Operation Allied Force,

Adverse weather affected target acquisition and identification, increased risk to aircrews, and complicated collateral damage concerns. Cloud cover was greater than 50 percent more than 70 percent of the time. Weather conditions allowed unimpeded air strikes on only 24 of 78 days.²⁵

In Desert Storm, by 6 February, three weeks into the air war, roughly half of the attack sorties into Iraq had been diverted to other targets or cancelled because of weather related problems.²⁶

In Kosovo, the problem imposed by weather was partly overcome by the use of GPS-guided bombs, but the use of other types of guided bombs and unguided bombs was greatly restricted.

^{vi} The disparity in aircraft percentage capable and weapon percentage employed was probably caused, in part, by the limited stockpiles of some laser-guided bombs and weather.

^{vii} Unguided bombs accuracy has been improved by using a computed aim point displayed on a Heads-Up Display (HUD) in the cockpit. This computed aim point is based on simplified ballistics, assumed winds, etc. Longer range or higher altitude releases become increasingly less accurate as the time of fall increases the magnitude of minor errors in assumptions or ballistics. Appendix D contains additional information.

Depending upon the political and military situation, a lower delivery altitude may be appropriate to ameliorate the higher altitude release affects of limited visual acuity and weather. The increased risk to aircrew from enemy air defenses caused by the lower release altitudes could be balanced, at least partly, with Suppression of Enemy Air Defense (SEAD) aircraft supporting the mission. If a CINC provides guidance suggesting that the loss of any aircraft will have very large political implications, he may be forced to accept or adopt similar supplemental ROE. However, he should also be aware of the potentially significant implications these ROE may have on the effectiveness of his operation or campaign and certainly consider modifying them later.

Limitations in Targeting Information

Two additional limitations affecting the CINC with regard to the use of PGMs are associated with limitations in targeting information. The first of these problems is associated with quality and quantity. It is possible to provide some small percentage of PGM targeting information solely from aircraft-based avionics systems, such as Imaging Infra-red (IIR) systems. In fact, this technique was successfully used by F-111Fs in Desert Storm, which were able to find and target buried Iraqi tanks with heat-sensing IIR aircraft systems, and then use the aircraft's laser-guided bombs to destroy tanks. This procedure, dubbed "tank-plinking" was considered to have the greatest impact on Iraqi armor attrition, once initiated on 6 Feb 1991.²⁷ Although tank-plinking with LGBs was considered successful in Desert Storm, it constituted a very small portion of the targeting requirements for PGMs. The majority of the targeting information comes from intelligence sources, and the PGM appetite for detailed target information is voracious in order to provide either precise aimpoint coordinates or to adequately prepare the aircrew for precise visual target aiming.

General Colin Powell argued that during Desert Storm, the intelligence available “was probably the best in military history.”²⁸ On the other hand, he also acknowledged in the same report that theater and tactical commanders expressed a great deal of frustration about the lack of dissemination of the information to the operational wings. The frustration was based, in part, on the need for relatively detailed intelligence for weapons capable of targeting very precise DMPIs. The Gulf War Survey addressed the issues very well,

Unfortunately, pilots often flew with outdated pictures of the target or with no imagery at all. For some units, imagery was not critical. But since imagery was a standard part of mission preparation materials, all aircrews had come to expect it. It was not good enough to read a message that described the target and its surroundings; they wanted and expected to see a picture of it. Although the intelligence community had successfully provided imagery for target folders for crew study in peace-time, the demand in wartime for imagery and imagery-derived products was not met.²⁹

Thus, although a CINC may have PGMs and trained aircrews at his disposal, now more than ever, without adequate intelligence support, a CINC faces serious limitations. Two good examples of the strategic implications of less than perfect information at the tactical level are the Al Firdos bunker bombing during Desert Storm, which effectively ended the strategic bombing of Baghdad targets, and the Chinese Embassy bombing in Operation Allied Force, which had a similar “CNN-effect”. In light of the latter Embassy bombing (caused by outdated, inaccurate intelligence), the foreshadowing observation made in the first line of the *Gulf War Survey* quote above relative to outdated imagery provides a clear indication that significant problems remain.

A second aspect of limitations in targeting information comes in the form of mobile targets, which in the last two wars has revealed several problems. In Desert Storm, air power had great difficulty in finding, targeting and accurately assessing damage to mobile targets such

as Scud missile launchers. Later, during Allied Force, the difficulty in finding and attacking mobile targets came in the form of Surface-to-Air Missile (SAM) sites. During Desert Storm, nearly every type of strike and reconnaissance aircraft employed in the war participated in the attempt to bring the mobile Scud missile threat under control, but with little success.³⁰ The problem in countering this type of threat lie not in the size of the warhead or the precision of its delivery, but in detection and then in directing ordnance on target once detected. The difficulty in detecting mobile targets was the result of Iraq's use of concealment, deception, dispersal, redundancy and mobility.³¹ All four of these techniques greatly complicated the problem of mobile target destruction in both Desert Storm and Allied Force. That is not to say that the attempts to negate these targets were completely without success. In Desert Storm, the heavy emphasis in searching for Scuds, and enemy efforts to counter the search limited missile effectiveness. During the first seven days of the war, 33 Scuds were launched (4.7 launches/day), while 55 Scuds were launched in the succeeding 36 days (1.5 launches/day).³² Likewise in Allied Force, although NATO forces were unable to destroy the Serbian air defenses, they were largely effective in suppressing them locally with the use of HARMs, which forced the SAM operators to limit their operations in fear of attack. As these difficult targets become higher priority to the CINC, it remains difficult to determine success in their destruction (termed Battle Damage Assessment or BDA) because of the use of decoys. During Desert Storm, for example, roughly 80 mobile Scud launchers were claimed to have been destroyed by aircrew, but most, if not all of these targets were later found to be decoys (a technique made even more effective by forcing aircrew to flying at higher altitudes).³³ The implications of these problems on the employment of PGMs are really two-fold. First, it remains very difficult to provide adequate intelligence to effectively (accurately and timely)

locate mobile targets, and second, it remains difficult (even with PGMs) to distinguish decoy targets from actual targets. This is important in attempting to locate other concealed and dispersed high-priority targets, like the high priority Nuclear-Biological-Chemical (NBC) targets in Desert Storm. Despite the priority of NBC targets in Desert Storm, and the heavy use of PGMs, success in hitting these targets was also limited.³⁴

In summary, while PGMs have demonstrated a remarkably effective capability to destroy many types of targets, including hardened targets, their use requires substantial, timely and accurate intelligence support. In addition, even with intelligence support, PGM effectiveness against targets that are mobile, or make heavy use of concealment or decoys remains problematic. Adversaries in recent wars have attempted to leverage each of these limitations by “not coming out to play”. This should not be considered a wholly unexpected tactic given the asymmetric technical advantage the U.S. enjoyed. During Desert Storm, in the wake of what would become an impressive 33:1 air-to-air kill ratio, Saddam Hussein initially attempted to conceal his aircraft in hardened shelters, and then later attempted to disperse them to Iran. Similarly, Serbian forces made excellent use of concealment, decoys and mobility in maintaining their SAM force. Using their SAM force sparingly while maintaining the SAM force ‘in being’ provided almost as great a threat as if it were used more frequently. Based on the success of this approach, and the difficulty in using PGMs to counter it, it is critically important that a CINC be cautious to avoid planning a war with the intent to heavily leverage the capabilities of PGMs against these types of targets.

Cost Imposed Limitations

The last PGM limitation addressed, but certainly not insignificant, is the cost associated with PGM technology. While guided bombs like the JDAM are relatively inexpensive, guided

missiles and rockets are not. The table below summarizes the comparative costs associated with the weapons that were expended in the Gulf War. Among the benefits of using self-powered guided missiles and rockets is the ability to extend the employment range, potentially decreasing the time a host aircraft is vulnerable to attack, but it clearly comes at a cost. Although not shown, the cost of a cruise missile such as the Tomahawk Land Attack Missile (TLAM) is roughly \$1 million each.³⁵

Table 1. Cost Comparison of U.S. Weapons Expended in the Gulf War³⁶

	Total Number	Total Cost
Unguided Bombs	209,940	\$431,960,550
Guided Bombs	9,473	\$307,592,641
Air-to-Surface Missiles (Primarily Maverick)	5,647	\$550,797,084

The obvious implication of these data is that these bombs are not only expensive, but will also be limited in quantity. In fact, the availability of JDAMs, some LGBs, and TLAMs during Operation Allied Force was limited. Although contracts have since been put in place to expand existing inventories, their cost in the fiscally constrained defense budget is not trivial and could ultimately limit the use of this technology as much as any of the other factors noted. Finally, while inventories are increased, it will be important for CINCs to ensure that Afloat Propositioning Ships (APSs) are adequately stocked to ensure that the initial enemy advances can be effectively countered using PGMs if and where they make sense to use.

JUST BECAUSE WE CAN, SHOULD WE?

Within the constraints and side-effects already identified, air power capabilities conferred by existing and emerging technologies have provided the survivability, intelligence and precision necessary to effectively attack targets that were previously either politically

beyond reach because of the risk in collateral damage or practically beyond our capability.

Yet, quite aside from the issue of our *ability* to effectively use this technology against given targets, remains an issue of central importance in effectiveness: the issue of doctrine.

Specifically, now that we have developed our precision capability, are we sure that our doctrine supports selection of the correct targets?

Airmen have long embraced the ideal that, “To a great extent, airplanes obviate the need to confront terrain or the environment because of their ability to fly over armies, fleets and geographic obstacles and strike directly at a country’s key centers.”³⁷ Acceptance of this ideal implies an understanding of what comprises a country’s ‘key centers’. Many early air power theorists including Giulio Douhet, Hugh Trenchard, and Billy Mitchell suggested that the ‘key centers’ were not the military forces themselves, but rather that they were to some degree the population. Douhet expressed the following rather extreme views.

Any distinction between belligerents and nonbelligerents is no longer admissible today either in fact or theory. Not in theory because when nations are at war, everyone takes a part in it: the soldier carrying his gun, the woman loading shells in a factory, the farmer growing wheat, the scientist experimenting in his laboratory. Not in fact because nowadays the offensive may reach anyone; and it begins to look now as though the safest place may be the trenches.³⁸

A complete breakdown of the social structure cannot but take place in a country subjected to this kind of merciless pounding from the air. The time would soon come when, to put an end to the horror and suffering, the people themselves, driven by the instinct of self-preservation, would rise up and demand an end to the war –this before their army and navy had time to mobilize at all!³⁹

Certainly, the U.S. does not advocate directly targeting the general populace of a country, nor even its ruler. Nevertheless, it does appear that air power targeting doctrine has, since the very beginning, consistently supported approaches that to some degree intentionally “inconvenience” the general populace (See Appendix E for additional detail). This philosophy suggests that as a result of this inconvenience the populace will ultimately ‘rise up’ (as Douhet

stipulated) to remove their leader from power or at the least compel him to bend his will. Yet this philosophy has rarely, if ever, worked. More often, the effect is exactly the opposite of that intended, resulting in a galvanized will to resist the enemy and stronger popular support for the targeted leader. Even the horrific fire bombings of Japan during WWII, which certainly had the useful military effect of inducing a portion of the Japanese fleet to remain closer to their homeland, did not produce enough popular support to demand an end to the war.^{viii} More recently, technology has dramatically improved our capabilities so that today we discuss the ability to tailor targeting in order to achieve specific effects. We consider how comprehensive the effects of an attack should be and how long we would like the effects to continue. Turning off the electric power in Iraq was certainly vital as a pre-requisite to subsequent attacks during Desert Storm.⁴⁰ On the other hand, planning for the power to remain off-line well beyond these attacks appears to have actually supported the objective of inconveniencing the general population so that they might be induced to overthrow Saddam Hussein.^{ix} Likewise, similar attacks on the infrastructure of Serbia during Allied Force were designed, in part, to influence the general population. But there is no evidence that these impositions on the populace were in any way effective. Quite the contrary, the overwhelming evidence suggests that the opposite of these objectives was the effect ultimately achieved. The rock concert in Belgrade and the bullseye targets attached to the shirts of Serbs are indicators that the intended results were far from achieved. In broader terms, the fact that Saddam Hussein and Slobodan Milosovic remain strongly in control of their respective countries supports the thesis that our targeting doctrine in support of indirectly attacking the national will of the populace, which has remained basically

^{viii} This direct attack of the enemy's homeland may also have provided a much-needed 'incremental victory' for the US public, which helped maintain popular support for the war effort.

^{ix} Acceptance of collateral damage should be based upon a balance between the military importance of a given target and the expected collateral damage.

unchanged since WWII, may not be effective. In fact, it has typically produced the exact opposite of the intended results and increasingly invites world criticism as well. A CINC should consider the historic ineffectiveness of this doctrinal approach in using precision weapons. Although it may prove very difficult to change this ingrained doctrinal approach, reliance upon it may result in failure and public outcry.

CONCLUSION

The U.S. and its allies and coalition partners have fared very well in the last two wars, in many ways as the result of new technologies in the form of PGM and, for the US, stealth capabilities. These new technologies integrate the principles of offense, economy of force, effects of mass, and surprise. Beyond the heralded successes, however, several important conclusions about limitations associated with the use of PGMs have also emerged.

First, there is an increasing public and political expectation and demand for relatively bloodless wars, brought about by the initial successes of PGMs in precisely targeting structures and equipment and the ability to hold collateral damage to incredibly low levels. This expectation has set a very high bar for the conduct of future operations that if unmet could result in the premature end to the conflict relative to the desired political or military endstate. Prematurely ending operations may result in prolonged and continued operations in the aftermath of the war, as in the case of Operations Northern and Southern Watch. Similarly, lopsided victories as the result of significant asymmetric advantage inherent in PGMs or other similar technologies may also result in a premature end to hostilities if it is perceived as “piling on”. Although the concept of careful integration of military and political instruments, particularly during conflict termination is not new, it now includes several new issues.

Next, in the wake of demonstrating an increasing ability to significantly limit collateral damage and conduct operations with the loss of only two aircraft, other CINCs will likely be held to the same standard and expectation in future operations. This virtual requirement may drive unbalanced risk assessments and supplemental ROE that may limit effectiveness, and potentially put more people at risk through a more prolonged war than necessary. A CINC will continue to face difficult decisions in balancing the need to avoid unnecessary exposure of airmen to enemy air defenses with the requirement to accomplish the desired objective. The decisions should be based upon the capabilities of the enemy, the physical environment, the phase of the operation and required effectiveness. A key to success will continue to be frequent review of ROE for a good balance.

Third, intelligence has always been an important and limited resource, but the effective use of PGMs demands an even greater emphasis in this area to support targeting and damage assessments. Recent experience indicates continued problems exist in disseminating (not necessarily gathering) pertinent, accurate, and timely information for precise targeting. Because of the types of targets assigned, PGMs have clearly demonstrated the potential for tactical missions to cause both positive and negative operational and strategic effects. Information networks and the ability to "reach back" to larger U.S.-based intelligence organizations offer hope for improvement here, but attention must remain focussed on this requirement to ensure adequate intelligence is available at the unit level.

Similarly, recent experience has demonstrated difficulty in effectively integrating intelligence and operations against targets that utilize concealment, deception, dispersal, redundancy and mobility. Intelligence must continue to work to provide timely and accurate targeting information as well as improved damage assessments against these types of targets.

Networked information flow will need to focus this information at tactical rather than strategic levels in order to allow rapid response. Rapid response targeting will be the key to working inside the decision cycle of the enemy and negating the potential problems associated with target mobility.

Next, PGMs remain a limited resource. Crisis response may not allow time to sufficiently deploy all resources needed in the theater. By positioning adequate levels of PGMs on APSs, a CINC will dramatically improve his initial combat capability and deterrence posture.

Finally, given the very capable resources offered to air power by new technologies, airmen are approaching (and may even have achieved) the survivability and precision always stipulated by current doctrine as a requirement to effective use of air power. But historic evidence suggests a need to question existing doctrine in light of its lack of success in causing an enemy leader to concede as a result of the destruction of civil infrastructure or an induced popular uprising.

Recent experience has made it clear that air power is a very effective tool, and is increasingly relied upon, particularly in politically constrained wars. In addition, air power brings with it remarkable new and developing technologies, making it increasingly more effective. However, these technologies can become two-edged swords for the CINC if he is unaware of the potentially significant limitations associated with them. The prospects for successful employment of air power can be enormous if the limitations are consciously considered, minimized and accepted by all concerned. The implications of not addressing the limitations can be failure for the CINC, the country and our allies or coalition partners.

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APPENDIX A

A BRIEF SUMMARY OF NEW TECHNOLOGIES IN AIRPOWER

There are a variety of new technologies in air power that, for the purposes of this paper, can conveniently be grouped into the following broad categories: PGMs, stealth, new engine technology, and integrated avionics. These categories will be briefly addressed in turn in order to provide a better understanding of the general capabilities they provide individually and, more importantly, in combination. Some of these capabilities exist in aircraft of today, thus offering an opportunity to gain insight into the effectiveness of the capability. For example, most front-line U.S. fighters and bombers of today (including the B-1, B-2, F-14, F-15, F-16, F/A-18, and F-117) have incorporated the ability to carry PGMs, while only a few aircraft of today are characterized as “stealthy”. Integrated avionics and advanced engine technology are included in some front-line fighters, but only in the most basic form. Fighters currently in development (Joint Strike Fighter and F-22) have been designed to include all of these technologies together.

PGMs

The first category of capabilities is Air-to-Ground Precision Guided Munitions, which include Infra-Red (IR), laser-, TV-, and GPS-guided munitions. The capability evident in these munitions represents an evolution that began with unguided bombs. The introduction of bombsights and the use of bomb release tables provided a means of achieving accuracy, but required the aircrew to release the bomb at a predetermined altitude, airspeed, dive angle and load factor *simultaneous* with the aimpoint reaching the target. Errors in precisely achieving the pre-determined release conditions added to errors in aiming, wind, etc. These errors were exacerbated by the “friction and fog” of combat where as Clausewitz indicated, even the simplest of tasks become difficult.

While PGMs were in their infancy, advances in avionics made it possible to incorporate an aircraft system that could constantly compute the predicted point of weapon impact given the existing aircraft conditions. The impact point was typically projected onto a Heads Up Display (HUD), which was a transparent combining glass that allowed the pilot to see a variety of avionics and weapons information superimposed on the outside world (more about this system is provided in Appendix D). This feature, common in current day aircraft, significantly improved unguided bomb accuracy, but was also subject to a variety of limitations including winds, relatively steady maneuvering near release, and the ability to visually acquire the target. Variations of this feature, such as using a self-contained laser to accurately range to the target (to refine ballistics inputs), made additional improvements.

Ultimately, however, additional precision was achieved by providing a means to guide the bomb. Initially, control of the guidance was rudimentary (sometimes “homing” on a signal, sometimes commanded by an aircraft). Today’s PGMs have relatively complex guidance systems that allow the weapon to track images selected or “locked-on” from an aircraft video display prior to launch. These systems also suffered from the requirement that the aircrew see through weather, smoke etc. The introduction of GPS-guided munitions in 1996 (addressed in Appedix B) relieves even this requirement, but requires precise target coordinates and GPS satellites for guidance, but is still regarded as an “accurate” bomb. The introduction of stealth in combination with PGMs provided not only the desired accuracy for effective precision bombing but also the necessary survivability to make it usable. The incredible losses sustained during the October 1943 Schweinfurt ball-bearing bombing attack (62 of the 228 bombers were lost and an additional 138 were damaged) were much more important than the relatively poor accuracy they achieved in motivating WWII leaders to reconsider the existing doctrine of

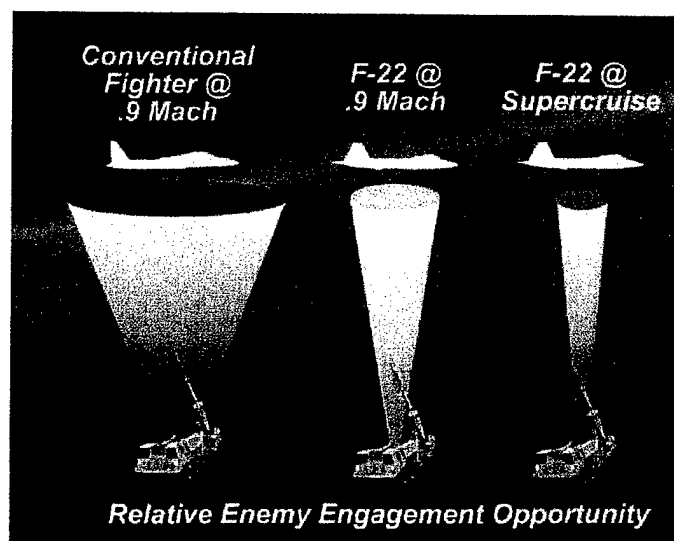
unescorted bombing.¹ Survivability today, particularly in politically constrained wars, is at least as important.

Stealth

The term “stealth” is typically associated with a reduction in radar observability, which often uses Radar Cross Section (RCS) as a measure of effectiveness. In practice, however, many additional “observables” are considered. Heat (or IR), visual, sound and electronic signatures may also be observed, so the design of a vehicle intending to be “stealthy” must include reduction of all of these signatures.

The object of designing a stealthy aircraft is to reduce all the signatures so that the aircraft either can not be detected with existing equipment, or at least to reduce it or delay it long enough so that there is insufficient time to react (principle of surprise). As a result, stealth aircraft (including the F-117, B-2, JSF, and F-22) enjoy a decreased effective range from enemy systems (such as SAM and AAA radars) because of the reduced signatures available to track. The reduced engagement zone, depicted in figure A1, provides greater freedom of movement and maneuver as well as the obviously increased surprise and offense.

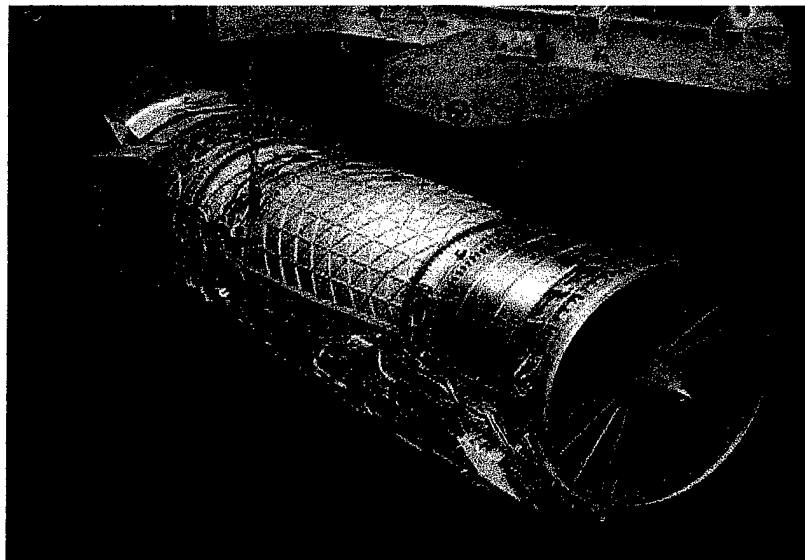
Figure A1. Effects of Stealth on Engagement Opportunity²



New Engine Technology

Also evident in figure A1 is the idea that speed, in combination with stealth, further reduces the time available to engage an aircraft in addition to the reduction offered by stealth alone. Advances in engine technology have provided the means of achieving higher speeds within a constrained size and weight envelope, as well as improvements in reliability. Engines installed in current fighter-class aircraft have increased thrust levels from 20-25,000 lbs to as much as 28-30,000 lbs over the last 10 years. New engine technology, evident in engines like 35,000 lb class engine in figure A2, has continued so that “supercruise” capability (the ability to fly supersonic at reduced, non-afterburningⁱ, power settings) is now available to future fighter aircraft. Note also that the engine in figure A2 provides a two-dimensional thrust vectoring capability along with the higher thrust levels to enhance maneuvering as well as speed.

Figure A2. New High-Thrust, Two-Dimensional Thrust Vectoring Engine³

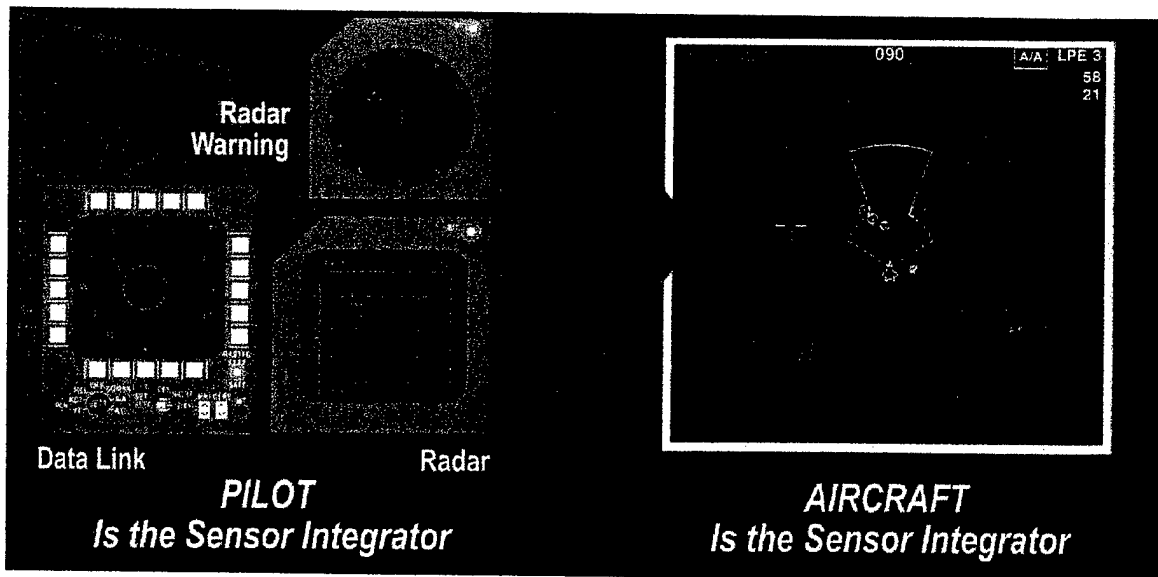


ⁱ Afterburner is a means of greatly increasing thrust by spraying and igniting fuel into the engine behind the turbine section. While it increases thrust substantially, it also dramatically increases the amount of fuel burned.

Integrated Avionics

Integrated or “fused” avionics refer to the capability to gather avionics information from a variety of onboard sources (like radar, electronic warning, data link, etc.), and possibly from other sensor aircraft, and integrate or “fuse” them into a single, meaningful picture of useful knowledge. The objective is to replace the many sources of *data* that offer pieces of the battlespace picture (integrated in the aircrew’s mind), with a single source of integrated *information* as depicted in figure A3.

Figure A3. Integrated Avionics Representation⁴



By digitally fusing the data, information not evident in a “federated” system can be obtained. For example, although the radar may “see” an aircraft, it may not know whether it is friendly or enemy. By using other on-board (or off-board) data, it becomes possible to determine the nature of the aircraft, and then correlate a radar warning receiver detection to the same aircraft. This integration could be depicted on a single display to help the aircrew quickly understand that the aircraft detected is an enemy, and has just “locked” your aircraft with its

fire control radar. The idea is phrased as “managing the battle, not the data”. This technology provides a means of using networked information, particularly when it is linked to other sources such as Airborne Warning and Control System (AWACS), Joint Stars, Naval Aegis systems, and space based systems.

The capabilities offered by each of the new technology categories addressed are impressive when considered alone, but become magnified as they are combined with the other technology categories. Many present-day U.S. aircraft take advantage of one or two of these technologies to some degree, but also have plans to incorporate as many of them as possible in order to increase the existing aircraft effectiveness. New aircraft like the Joint Strike Fighter and F-22 are being designed to take a greater advantage of them all.

ENDNOTES

¹ Department of Defense, The United States Strategic Bombing Survey, (Washington, DC: US Government Printing Office, 30 Sep 1945), p. 5.

² “F-22 Raptor... The Keystone of Air Dominance for the 21st Century,” (Marietta, Georgia: Lockheed Martin Tactical Aircraft Systems Marketing, 1997), p. 12.

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APPENDIX B

JDAM

The Joint Direct Attack Munition (JDAM) is a relatively low cost kit that is designed to convert unguided bombs in existing inventories to “accurate” guided bombs.¹ The tail section contains a GPS receiver that can be used despite adverse weather. This feature is an important distinguishing feature from most other guided weapons, which are limited by cloud, dense fog, smoke, etc. The glide range or “standoff range” for the JDAM is up to 15 miles. Over 245 JDAMs have been dropped since 1996, which have achieved a 9.6m CEP accuracy despite the 13m requirement.²

Figure B1. JDAM release from an F-16

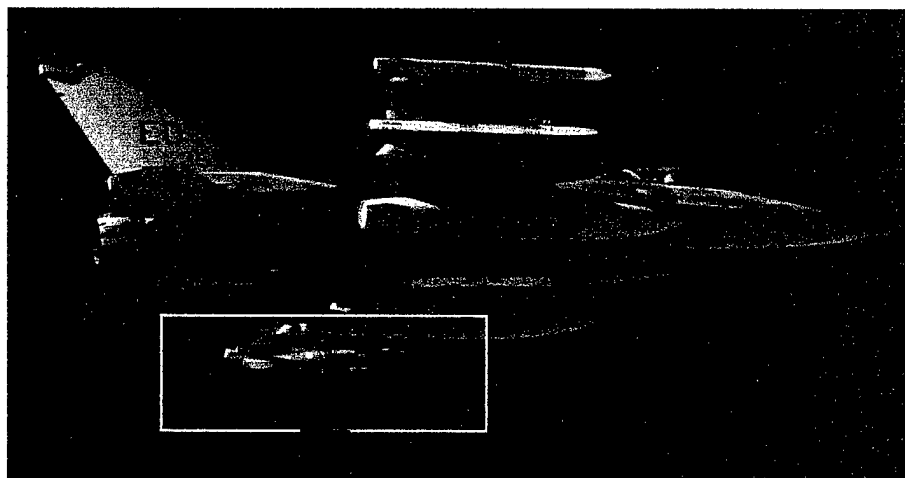
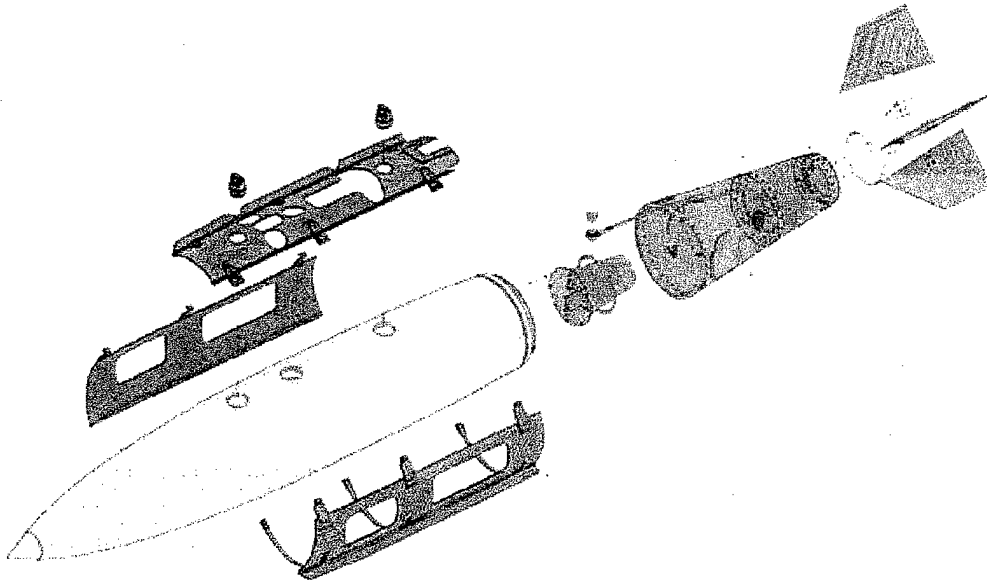


Figure B2. Composition of a JDAM³



The yellow bomb body, shown in figure B2, is unchanged from the basic unguided bomb. The other parts are “strapped on” to provide additional stability, guidance and flight control. A summary of JDAM information is provided below in table B1.

Table B1. Summary of JDAM Specifics⁴

- Inertial Navigation System/Global Positioning System guidance
- Tail kit for
 - MK-83/BLU-110 (1000 lbs)
 - MK-84/BLU-109 (2000 lbs)
- 15 NM Range
- Circular Error Probable (CEP)
 - SPEC: 13m
- Cost:
 - \$14,000-\$18,000 each
- Contract for 3139 kits (800 to date)
- Expect 87,500 over the next decade for the U.S. and additional International sales

ENDNOTES

¹ "Accurate" munitions are distinguished from "Precision" weapons by virtue of the former's slightly decreased accuracy compared to the latter. Technically, based on the specified accuracy of the JDAM, JDAM is more properly termed "accurate" rather than "precision".

² "Joint Direct Attack Munition (JDAM)," <<http://www.boeing.com/defense-space/missiles/jdam/jdam.htm>>, (20 Mar 2000).

³ "JDAM technical specifications," JDAM - The Smart Solution--Affordable, Accurate, Autonomous, Adverse Weather, < <http://www.boeing.com/defense-space/missiles/jdam/jdamspec.htm>>, (20 Mar 2000).

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APPENDIX C

SUMMARY OF GULF WAR TARGET-TO-SHOOTER COMPARISONS

The following summary provides comparisons between stealth and non-stealth forces during the Gulf War. However, the only stealth platform used during Desert Storm was the F-117, which also employed GBU-27 laser-guided bombs. Based on these facts, the information below actually reflects a comparison between stealthy PGM shooters and non-stealthy, "dumb bomb" shooters.

The data presented in table C1 compares the first non-stealth/non-PGM attack to the first stealth/PGM attack. The measures of effectiveness are not only the 1200% increase in target coverage per aircraft, but also the 47% fewer aircraft. In addition, these measures do not reflect the typically higher probability of kill associated with the use of PGMs.

Table C1. First Stealth Attack vs. First Non-Stealth Attack¹

1st Non-Stealth Attack	1st Stealth Attack
4 A-6 Attack 4 Saudi Tornados 4 F-4G SEAD ⁱ 5 EA-6B ECM ⁱⁱ 17 F-18 SEAD 4 F-18 CAP ⁱⁱⁱ	20 F-117 Attack
38 Aircraft; 8 Bombers 3 DMPIs	20 Aircraft/Bombers 37 DMPIs

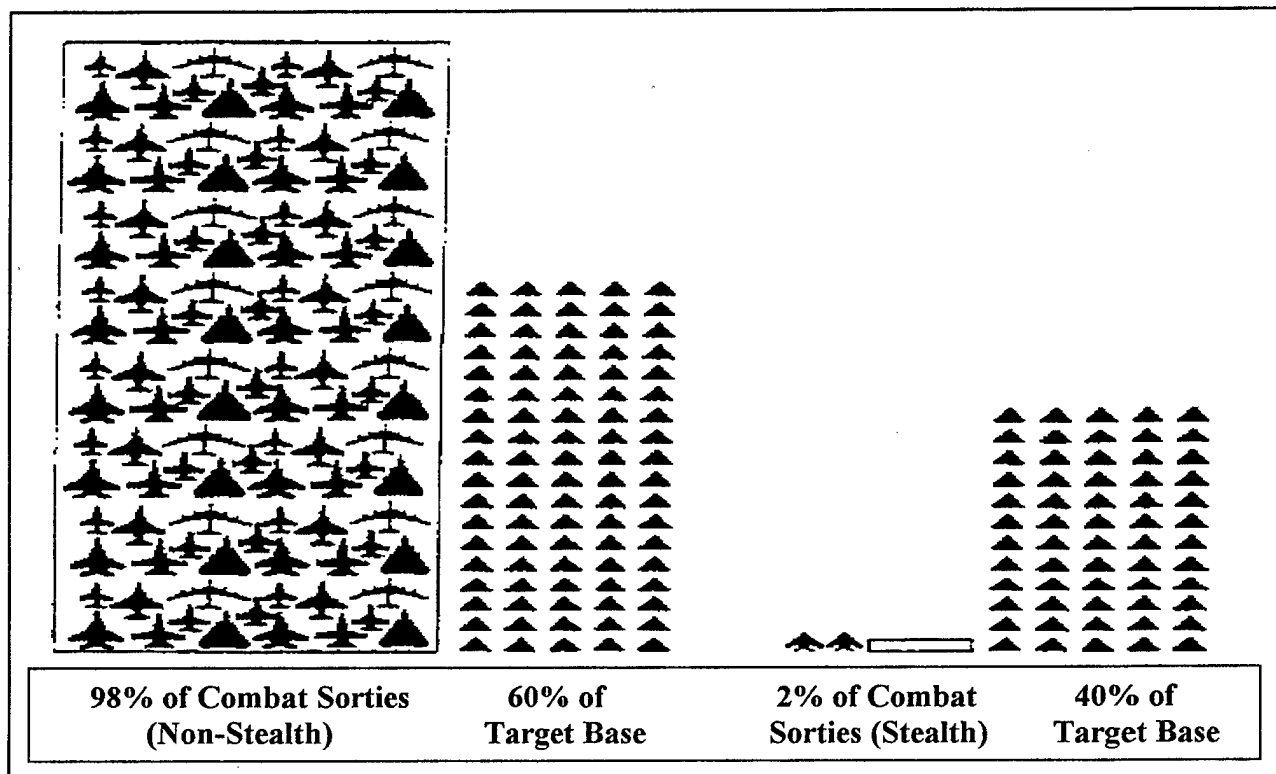
ⁱ. Suppression of Enemy Air Defense Mission

ⁱⁱ. Electronic Counter Measures (Jamming)

ⁱⁱⁱ. Combat Air Patrol (Air Escort)

This increased effectiveness became even more striking when considered across the entire war. Data presented in figure C1 depict similar information based on accumulated sorties throughout the entire Gulf War. In addition to the increased

Figure C1. Gulf War Summary of Stealth vs Non-Stealth Target²



effectiveness evident in the figure and table, is the ability to achieve surprise not only because of the stealth technology, but also because of the smaller force size. Similarly, fewer aircraft, at least in a general sense, require less logistics and security support. However, in another sense, the support requirements for these PGM shooters require additional intelligence to enable precise targeting. Stealth aircraft also have unique security and maintenance requirements, which must be considered. Overall, however, the stealthy, PGM equipped aircraft demonstrated remarkable effectiveness in the Gulf War.

ENDNOTES

¹ David A Deptula, "Firing for Effect: Change in the Nature of Warfare," Aerospace Education Foundation Paper, 24 August 1995, p. 9.

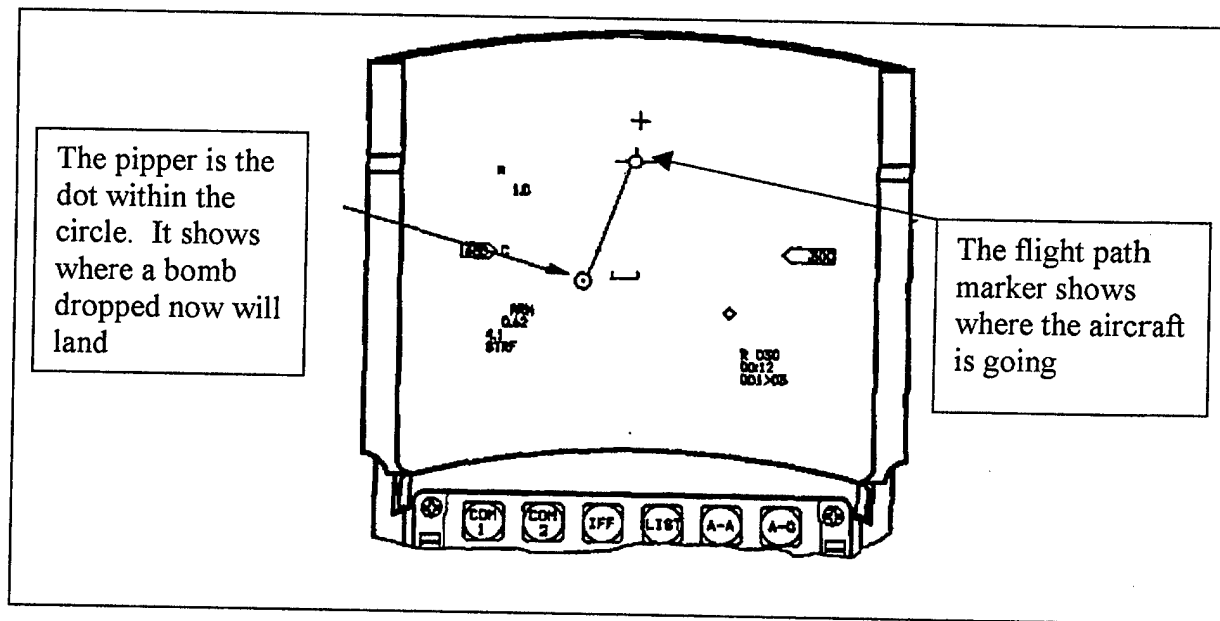
² Ibid., p. 10.

APPENDIX D

CONSTANTLY COMPUTED IMPACT POINT FOR UNGUIDED BOMBS

Improved accuracy for unguided bombs has been achieved through a variety of methods, one of which includes an aircraft-calculated "Constantly Computed Impact Point". This mode of weapons delivery makes use of a variety of aircraft-based (vs. weapon based) data to constantly compute the predicted point of impact if the bomb were released at any given moment. The solution is presented to the pilot through a "pipper" or aimpoint superimposed on a transparent combining glass called a Heads Up Display (HUD) as shown in figure D1. In addition to airspeed, attitude (dive and roll angles), altitude and wind drift, the aircraft computer uses precise range information provided by the aircraft radar. The aircraft computer then uses this information along with known ballistics data associated with a particular bomb to continuously compute the impact point and display the solution on the HUD.

Figure D1. Pipper (Aimpoint) Display on a Heads Up Display



The pilot employs the system by flying a pre-planned attack profile that ensures that the aimpoint will be positioned near the target at a pre-planned dive angle and airspeed. If the pilot varies from his pre-planned attack, he may still hit the target as long as he puts the pipper on the target when he pushes the bomb release button. Variations from the planned attack profile may influence his ability to safely recover the aircraft, avoid the fragmentation caused by the bomb he released, or decrease the desired blast effect (bomb effects are a function of many things including impact angle). There are several variations of this basic system, for example, the use of an on-board laser may provide an improved range data source over that provided by the radar, resulting in an overall increase in accuracy.

There are a variety of limitations associated with this system including variations in wind and non-steady conditions at release. In addition, the system still relies on the ability of the pilot to fly the aircraft over the target and put the aimpoint on the target at the time of release. Weather, fog, smoke, etc. will also hamper his ability to visually acquire the target potentially making the system completely ineffective. Although not nearly as precise or consistent as PGMs, this system has become very effective in achieving relatively accurate weapons delivery with unguided bombs in most present day aircraft.

APPENDIX E

AIR TARGETING DOCTRINE

Within the constraints and side-effects already identified, air power capabilities conferred by existing and emerging technologies have provided the survivability, intelligence and precision necessary to effectively attack targets that were previously either politically beyond reach because of the risk in collateral damage or practically beyond our capability. Yet, quite aside from the issue of our *ability* to effectively use this technology against given targets, there remains an issue of central importance in effectiveness: the issue of doctrine. Specifically, now that we have developed our precision capability, are we sure that our doctrine supports selection of the correct targets.

At the beginning of WWII, President Roosevelt tasked the Secretary of War to determine their requirements to win the war in Europe. This tasking ultimately resulted in a list of prioritized target categories for strategic bombardment.¹ Those prioritized categories are, in many ways, very similar to the prioritized categories of today as summarized in Table E1.

Table E1: Comparison of Target Categories AWPDP-1 and “Five Rings”

Air War Plan Document (AWPD-1) ²	Warden’s Five Rings ³
Electric System	Leadership
Transportation System	Key Production
Oil & Synthetic Fuel Plants	Infrastructure
Aircraft Factories	Population
Aluminum & Magnesium Plants	Fielded Military

Clearly the categories from the WWII list match well with the second and third categories in the today’s widely accepted “Five Rings” model. In the latter model,

Warden argues that the key is the center ring, or leadership, and the surrounding rings represent things that protect or enable the leadership. In addressing the fourth ring "population", Warden wrote, "Indirect attack on the population, such as North Vietnam used against the United States, may be especially effective if the target country has a relatively low interest in the outcome of the war."⁴ This statement provides implicit acceptance, even endorsement of the concept of attacking enemy key production and infrastructure because of the indirect impact it has on the populace and their will to support their leadership.

ENDNOTES

¹ James C. Gaston, Planning the American Air War, (Washington DC: National Defense University Press, 1982), pp. 13-14.

² Ibid., p. 107.

³ John A. Warden, "The Enemy as a System," Airpower Journal, Spring 1995, pp. 46.

⁴ Ibid., p. 49.